Journal of Mechanical Engineering and Sciences
ISSN (Print): 2289-4659; e-ISSN: 2231-8380
Volume 13, Issue 1, pp. 4575-4595, March 2019
© Universiti Malaysia Pahang, Malaysia
DOI: https://doi.org/10.15282/jmes.13.1.2019.16.0386

An investigation into tapping of Al6061/SiC metal matrix composite with straight flute HSS machine tap

Nagaraja[1], Raviraja Adhikari[2*], and T. Yasir[3]
[1,2] Faculty, Mechanical and Manufacturing Engineering, Manipal Institute of Technology,
Manipal Academy of Higher Education, Manipal, India
Phone: +919449328165; Fax: +9108202571071
*Email: ravi.adhikari@manipal.edu
[3]Post graduate student, Department of Mechanical and Manufacturing Engineering,
Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, India.

ABSTRACT

The present study deals with tapping of Al6061/SiC metal matrix composite. Stir casting technique was used for the fabrication of composite. Castings were produced by varying weight percentages of SiC (5%, 7.5% and 10%) of 23µm size in Al6061. The tapping experiments were conducted for the machinability study of Al6061/SiC metal matrix composite using M8 x 1.25 HSS machine taps. The tapping operation was performed under dry condition with different cutting speeds. Torque required for tapping was measured using piezoelectric based 4-component drill tool dynamometer. Surface morphology and profile of thread surfaces were analysed using Scanning Electron Microscope (SEM) and metallurgical microscope. Estimation of progressive flank wear of machine taps was undertaken using profile projector. The performance of HSS machine tap was evaluated in terms of tapping torque, tool flank wear, and surface characteristics of thread surfaces. The flank wear of uncoated HSS machine tap increased with the increase in weight percentage of SiC in Al/SiC composite for a particular cutting speed. Further, when the matrix materials were reinforced by the same kind and the same weight percentage of SiC particles, the flank wear of the tool was found to increase with cutting speed. In addition, the damage caused to thread profiles increased with the increase in cutting speed and weight percentage of SiC.

Keywords: Metal Matrix Composite; Al6061/SiC; stir casting; machine tap.

INTRODUCTION

The use of aluminium alloys in manufacturing industry has increased in recent years since they are lightweight and strong. The machining of aluminium alloys has increased proportions so that the chip volume is up to 80 % of the initial volume of the machined material in industry such as aerospace [1]. Metal Matrix Composite is a type of composite in which reinforcement material is embedded in a matrix material. The metal matrix composites have been one of the materials used in aerospace and automobile industry. Out of the various matrix materials, light metals such as titanium and aluminium have been chosen for industrial applications as the matrix materials.

The different methods of fabricating aluminium metal matrix composites and their application have been explored by Surappa [2]. Stir casting is accepted as a route for producing discontinuous metal matrix composites. Its applicability to a large quantity production is advantageous. It allows a conventional processing route to be used and hence reduces the cost of the product. It is one of the most economical routes for metal matrix composite production [3] and allows large size components to be fabricated. Sozhamannan et al. [4] studied the effects of processing parameters such as different processing temperatures and holding time in stir casting process and found that the viscosity of aluminium matrix decreases with increase in processing temperature. Skibo et al. [5] concluded that the manufacturing cost of composites using stir casting method was about one third of the other methods. The mechanical properties achieved by the reinforcements in metal matrix composites influence their machinability. Relatively, high tool wear [6] is the main concern during processing of metal matrix composites. Interaction of hard reinforcement particles with tool appears to be the main reason for tool wear. Ibrahim et al. [7] studied the effect of reinforcement particle sizes and cutting speeds on tool wear while turning Al/SiC metal matrix composite using CBN tool and found that flank wear was the main mode of tool wear. Kilickap et al. [8] did experimental investigation of tool wear and surface roughness while turning Al/SiC metal matrix composites using carbide tools at different cutting speeds, feed and depth of cut and found that the cutting speed was most influential machining parameter followed by feed and depth of cut affecting the tool wear. Surface quality was found to be better with higher cutting speed and lower feed rate. Dabade et al. [9] attempted to improve the machinability of stir cast Al/SiC composite by turning in hot condition using PVD coated carbide inserts and found that the feed and the preheating temperature have a significant influence on surface roughness and micro-hardness during hot machining. Beristain et al. [10] studied the machinability of Al/SiC metal matrix composites in turning operations using poly crystalline diamond and mono crystalline diamond tools and found that the built up edge was higher while machining with mono crystalline diamond tools than in the poly crystalline diamond tools. Abrasive wear was found to be predominant during the turning of Al/SiC composites [11].

Tapping is one of the widely used machining operations for obtaining internal threads. Considerable efforts have been made over the years to develop appropriate materials for machine taps. High speed steel (HSS) is one among those materials being used for the purpose. The study of factors affecting the wear of machine tap at various operating conditions and their implications on tool wear mechanisms, tool life, tool failure modes, and the quality of the surfaces generated on the work pieces is significant. If a tapping tool fails, the work material which has already accrued an added value, the cost of scrapping or reworking will be high. The breakage of a tap hinders the productivity of the process. A few research efforts on evaluating the performance of the HSS machine taps and their outcome have been reported. Gil et al. [12] developed an application which monitors the data coming from the current signal of the tap spindle to assess the thread quality as a result of tool wear. Saito et al. [13] used a tapping tool coated with Ni-P/cBN film which resulted in increase of coefficient of friction and reduced chip snarling problem during tapping when compared with the use of taps coated with TiCN film. While tapping AISI 304 stainless steel with HSS taps [14], the dominating factor affecting the tool life was the built-up-edge formation on the tools and multipass threading cycle was recommended to increase the tool life. Bratan et al. [15] developed a new design of taps with deforming and cutting teeth on each land which resulted in the increase of accuracy of threads cut in aluminium alloys. Bhowmick et al. [16] undertook tapping experiment on aluminium alloys and reported that transfer of aluminium onto the tool surface was the main reason for tool breakage. The aluminium chips formed during the dry tapping have a tendency of adhering to the flanks of threads in the tool and cause clogging of the tool in a very short period. Filho et al. [17] successfully demonstrated minimum quantity lubrication technique for tapping of aluminium alloys. Steininger et al. [18] conducted tapping experiments on the aluminium based alloys using carbide taps with TiCN, CrN, TiB2 and DLC coatings and concluded that the DLC coated carbide taps performed better than the other coated taps. In an aluminium based metal matrix composite with SiC particles as the reinforcement, aluminium being the major constituent, and the similar phenomenon is expected. The hard SiC particles would result in the progressive wear of tap. The significantly worn out tap with clogged thread flanks are likely to affect the quality of threads produced in the work material. Progressive wear of HSS machine taps used for producing threads in aluminium alloy metal matrix composite, and its effect on quality of threads are yet to be reported. This study is aimed at investigating the influence of weight percentage of SiC particles in the aluminium matrix of the composite, the cutting speed on progressive wear of HSS machine tap, and the quality of threads produced.

METHODS AND MATERIALS

The methodology adapted for estimating the progressive wear of taps is shown in Figure 1.

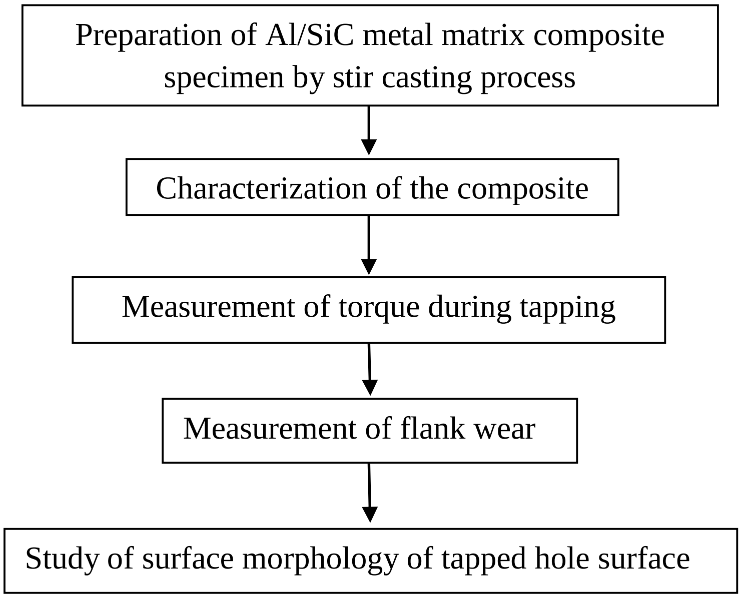


Figure 1. Methodology adapted for the experimental study

The aluminium alloy Al6061 was used as the matrix material for fabrication of specimens. The composition of Al6061 alloy used in the present study is given in Table 1. The aluminum alloy is reinforced with SiC particles in different percentages. The previous study [19] had reported that the SiC powder particles of 20 µm were more wear resistant than 3 µm particles. The present study has used silicon carbide powder of 23 µm size, as the reinforcement material.

Table 1. Chemical Composition of Al6061

Contents	Al	Si	Fe	Mn	Mg	Cu	Ti	Cr
Weight %	97.547	0.773	0.22	0.068	0.922	0.276	0.022	0.072

The stir casting set up used in the present work is shown in Figure 2. The Al6061 billets were melted in a graphite crucible by electric resistance furnace and melting allowed until a steady temperature of 800^0 C was attained. The entire melt was degassed using nitrogen. The degassing eliminates a variety of impurities that pose serious problems in the production of quality castings. Hydrogen is at the forefront of these impurities. The solubility of hydrogen in the molten aluminium increases with temperature. Solidifying metal must reject the hydrogen, otherwise resultant castings will suffer from porosity. One percent magnesium was added to ensure good wettability of SiC particles [20]. The molten alloy was agitated with a mechanical stirrer to form a fine vortex and the SiC particles preheated to 600º C were added at a constant feed rate to the aluminum melt at 780º C stirring continuously at a speed of 300-400 rpm for about 10 minutes. After stirring, the melt was heated to the liquidus temperature of 800º C and again stirred for 5 minutes at a speed of 300 rpm. Then the melt was poured into steel moulds preheated to 450º C. The molten metal was poured at 720º C. The preparation of castings was repeated with 5, 7.5, and 10 weight percentage of SiC particles.

Figure 2. Stir casting setup.

The cast Al6061/SiC specimens were machined to billets of size 120x45x10 mm. Holes were tapped in the specimen using HSS M8x1.25 straight, three fluted spiral point tap as shown in Figure 3a, with 9° chamfer angle and 22 mm flute length. The specimen was clamped on the top of piezoelectric based four component Drill tool dynamometer 9272A (Kistler make) which was used for measuring the torque during tapping. The tapping experiments were conducted on Computer Numerical controlled (CNC) vertical machining centre (M/s Ace Manufacturing Systems, India) at a feed rate of 1.25 mm/rev (pitch of thread) at the cutting speeds 12, 14, and 16 m/min. The material behavior of Al6061/SiC composite was expected to be in between aluminium alloy and cast iron. The cutting speed recommended for cast iron is 9-12m/min and for aluminium is19-22m/min [21]. Hence, the cutting speed for the tapping operation for the metal matrix composite was selected such that it lies between the cutting speeds recommended for these materials. Seventeen holes were drilled with 6.8mm diameter drill, before tapping each specimen. Fifty-one holes were tapped for each combination of weight percentage (5, 7.5, and 10) of SiC and cutting speed, using one tap. The arrangement used for conducting the tapping experiments on composites is shown in Figure 3b.

Figure 3a. HSS straight, three fluted spiral point tap, M8x1.25.

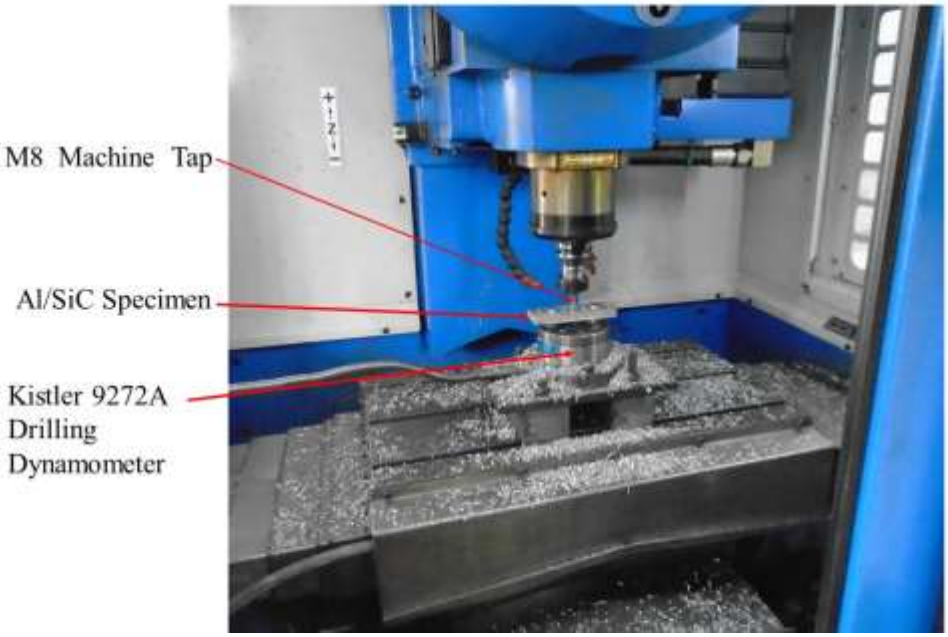


Figure 3b. An experimental setup.

The Dynoware software installed on a computer connected to the dynamometer through A/D converter and 5070A10100 charge amplifier gave the variation of thrust force and torque with respect to time, during tapping. A sample specimen with tapped holes is shown in the Figure 4.

Figure 4. An Al6061/SiC specimen with tapped holes.

The wear pattern of the machine tap was measured using the Profile Projector (METZER, India make). The profile measurement was done at a magnification of 20X. The profile of the teeth in the chamfer portion of the tap was traced from the display in the profile projector, before the start of tapping, as shown in Figure 5. Subsequently, the same procedure was repeated after tapping 13, 26, 38, and 51 holes. All the cutting edges in the chamfer portion including the first full depth thread at the end of a chamfer section undergo the progressive wear with the increase in number of holes that are tapped. In addition, the first full depth thread is responsible for cutting the thread to the desired size, as it is the last thread in the cutting section of a machine tap. Therefore, the progressive wear of the other cutting edges in the chamfer portion causes additional burden or load on the full depth thread to perform the task. Hence, the cutting edges of the first full depth thread are taken as the reference for estimating the progressive flank wear of the machine tap.

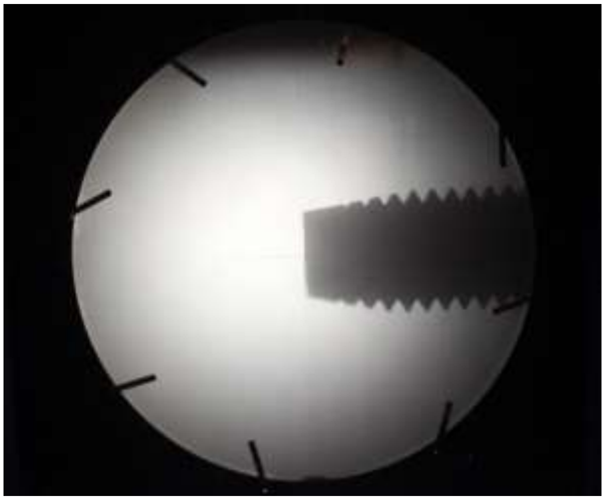


Figure 5. Display of tap profile in the profile projector.

The reduction in the height of cutting tooth (h) in the chamfer section is measured as shown in Figure 6. The flank wear was estimated after tapping 13, 26, 38, and 51 holes. The progressive flank wear (h_f) is obtained by marking the successive reduction in the height of the teeth in the chamfer portion of a tap on its original profile. The flank wear was estimated after tapping 13, 26, 38, and 51 holes. The progressive reduction in height of the tooth was marked as a point on rake face in each case. The horizontal lines were drawn from these points to intersect the flank surface. The progressive flank wear was estimated by measuring the length of each line. The procedure adapted is shown in Figure 7.

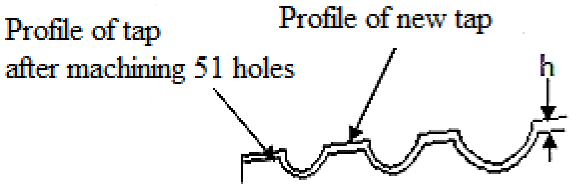


Figure 6. A profile of the chamfer portion of tap.

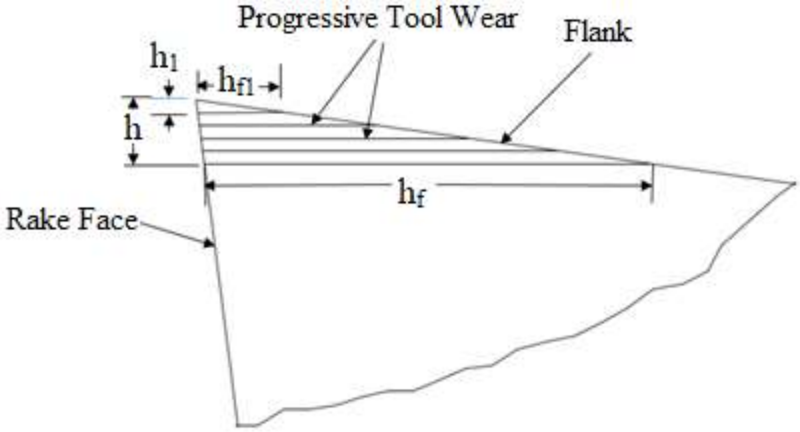


Figure 7. Flank Wear (h_f) derived from reduction in the height of the tooth (h).

RESULTS AND DISCUSSION

The assessment of performance of the tapping tool is done based on the progressive flank wear of tool, quality of threads and surface morphology.

Flank wear

The typical plot of torque captured in the Dynoware software during tapping is shown in Figure 8. It is observed that the torque increases gradually from the point of engagement of a tap with the hole and reaches its peak when the chamfer fully engages with the hole. The torque remains constant until all the cutting edges are engaged with the hole and it deceases steadily as the chamfered end of the tap moves out of the hole progressively. It reaches its minimum value when the chamfered end of the tap disengages from the hole. This trend is comparable to the one reported earlier [22].

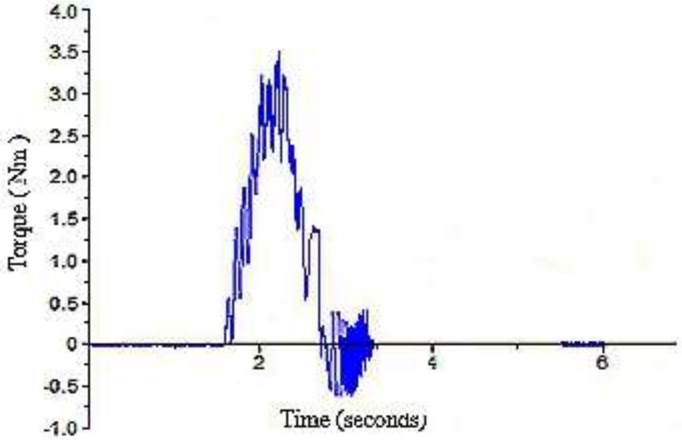


Figure 8. A sample plot for torque variation during tapping.

In general, it was observed that an increase in the weight percentage of SiC particles had increased the torque required as shown in Figures from 9 to 11. This is attributed to the increase in hardness and strength of the composite with the increased weight percentage of SiC [23]. Further, for a particular percentage of SiC in the composite, the increase in the cutting speed increases the torque that is required for tapping, as shown in Figures from 12 to 14. The rate of material removal increases with the increase in the cutting speed necessitating the increase in power and hence, the torque. Further, it was observed that an increase in weight percentage of SiC particles had increased the torque that was required. This is attributed to the increase in hardness and strength of the composite with the increase in weight percentage of SiC particles.

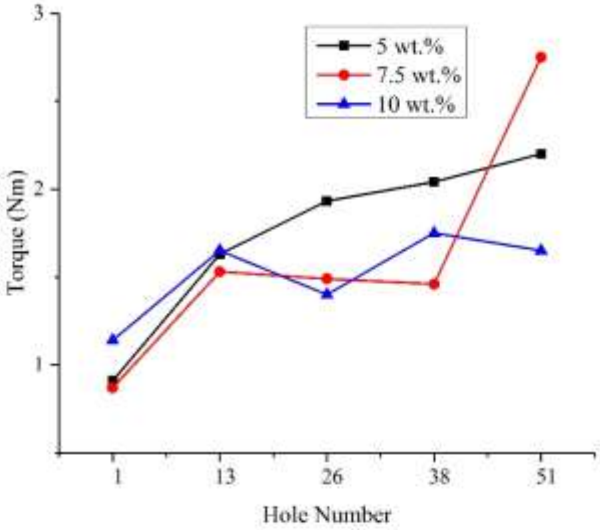


Figure 9. Torque while machining 1, 13, 26, 38, and 51 holes at 12 m/min speed for various weight percentages of SiC.

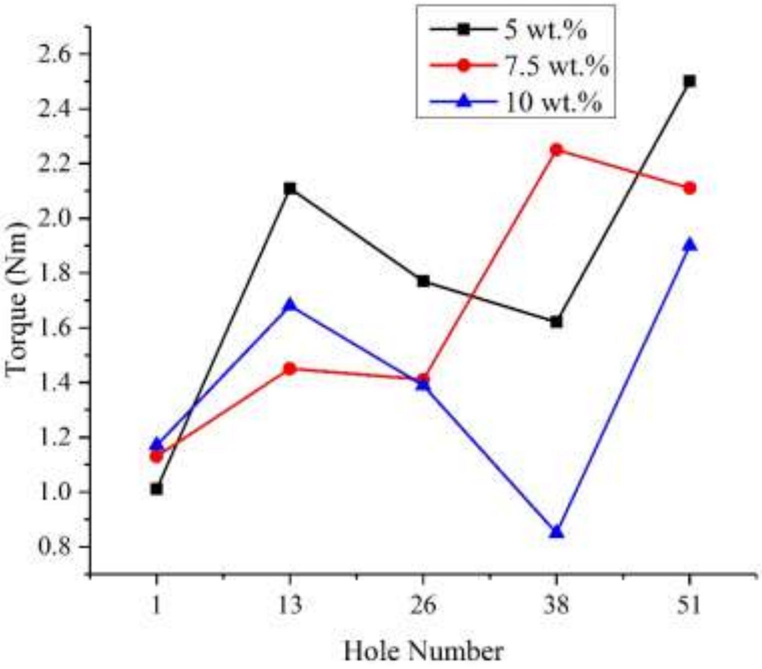


Figure 10. Torque while machining 1, 13, 26, 38, and 51 holes at 14 /min speed for various weight percentages of SiC.

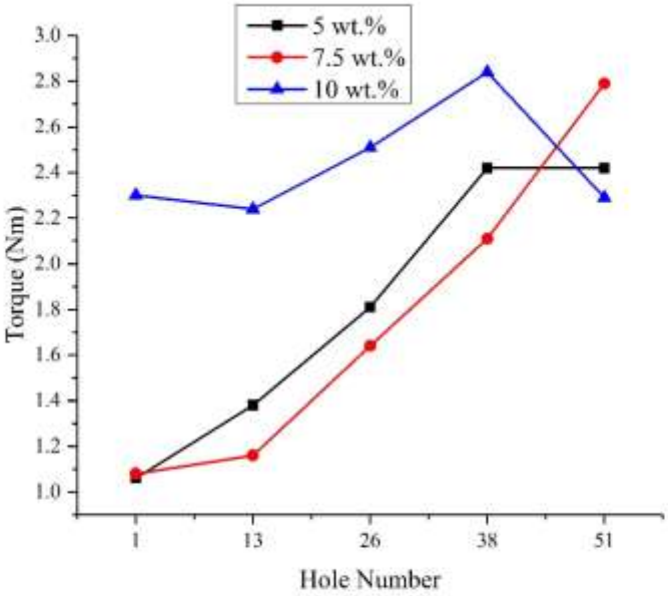


Figure 11. Torque while machining 1, 13, 26, 38, and 51 holes at 16 m/min speed for various weight percentages of SiC.

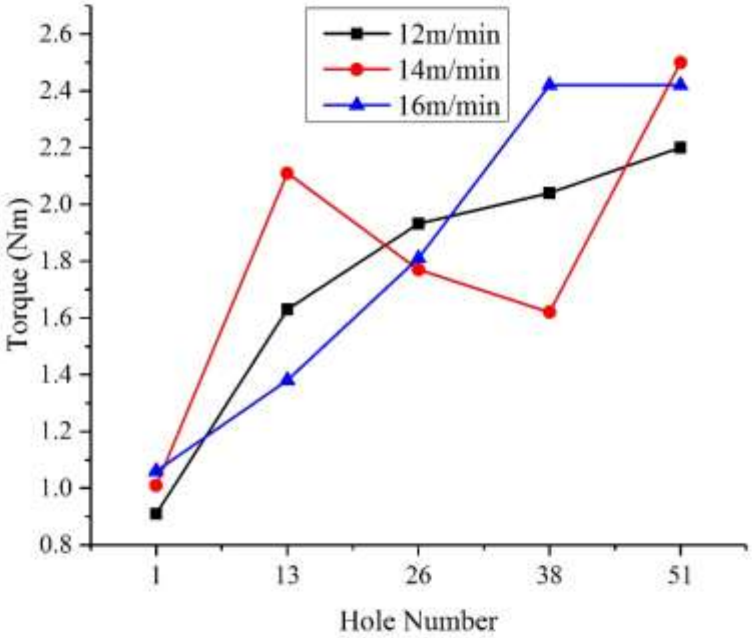


Figure 12. Torque while machining 1, 13, 26, 38, and 51 holes for 5 weight percentage of SiC at various speeds.

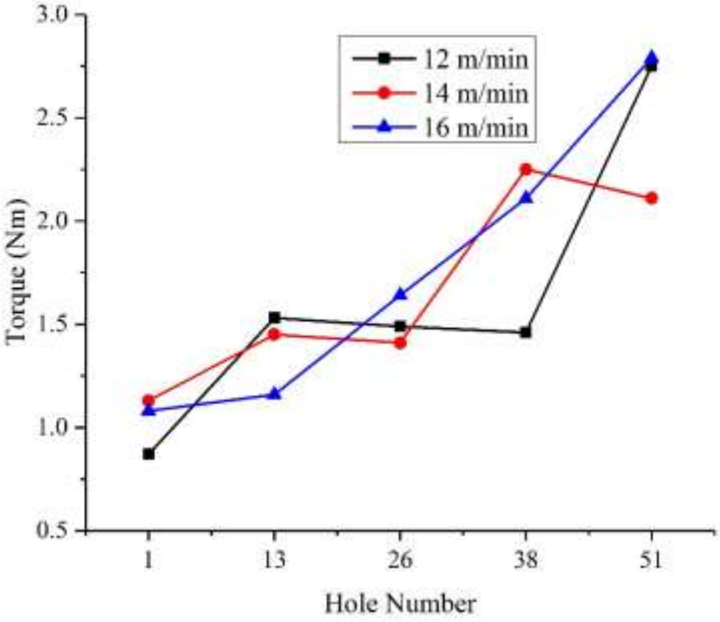


Figure 13. Torque while machining 1, 13, 26, 38, and 51 holes for 7.5 weight percentage of SiC at various speeds.

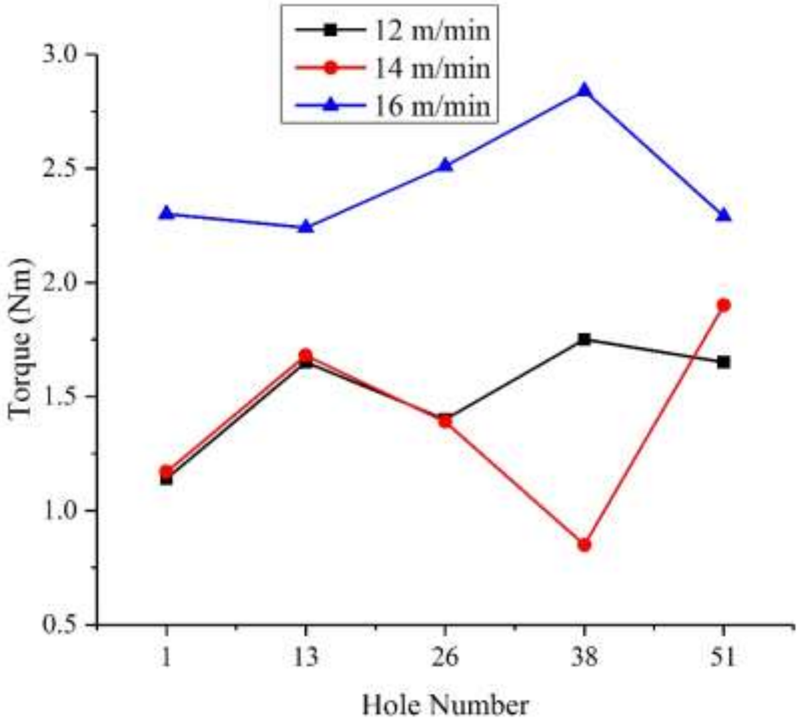


Figure 14. Torque while machining 1, 13, 26, 38, and 51 holes for 10 weight percentage of SiC at various speeds.

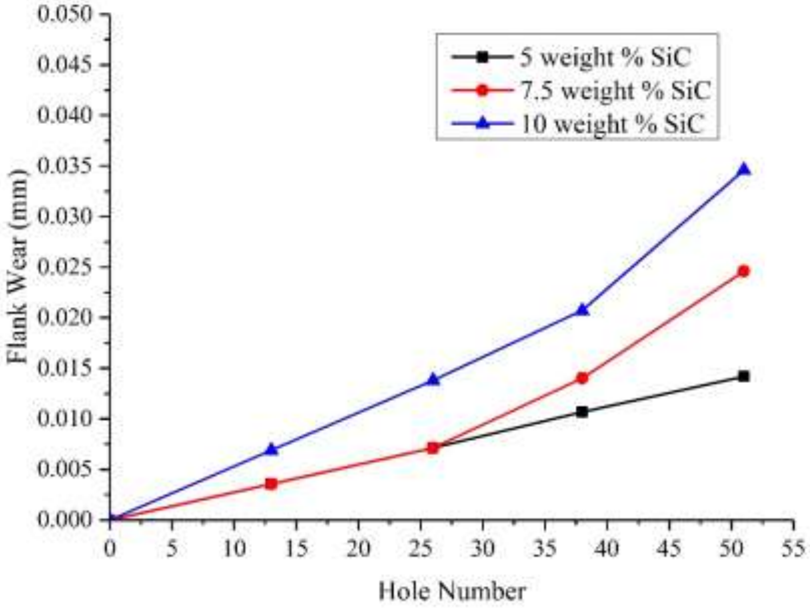


Figure 15. Flank wear after machining 13, 26, 38, and 51 holes at 12 m/min speed for various weight percentage of SiC.

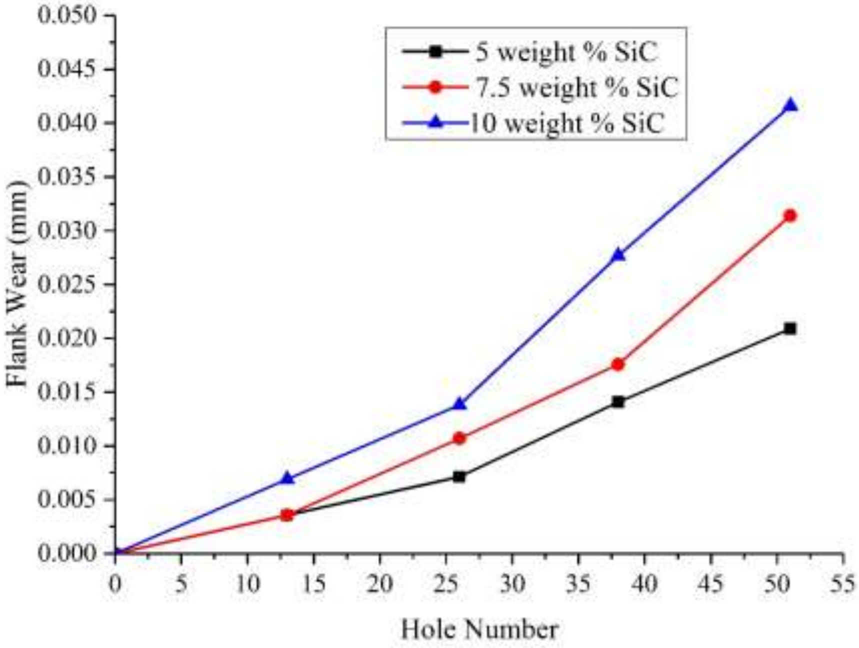


Figure 16. Flank wear after machining 13, 26, 38, and 51 holes at 14 m/min speed for various weight percentage of SiC.

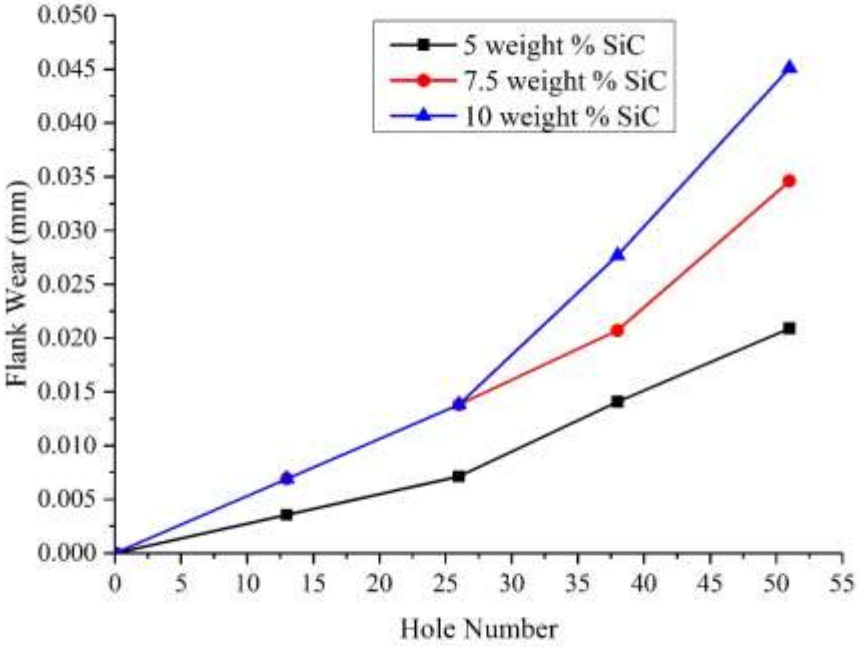


Figure 17. Flank wear after machining 13, 26, 38, and 51 holes at 16 m/min speed for various weight % of SiC.

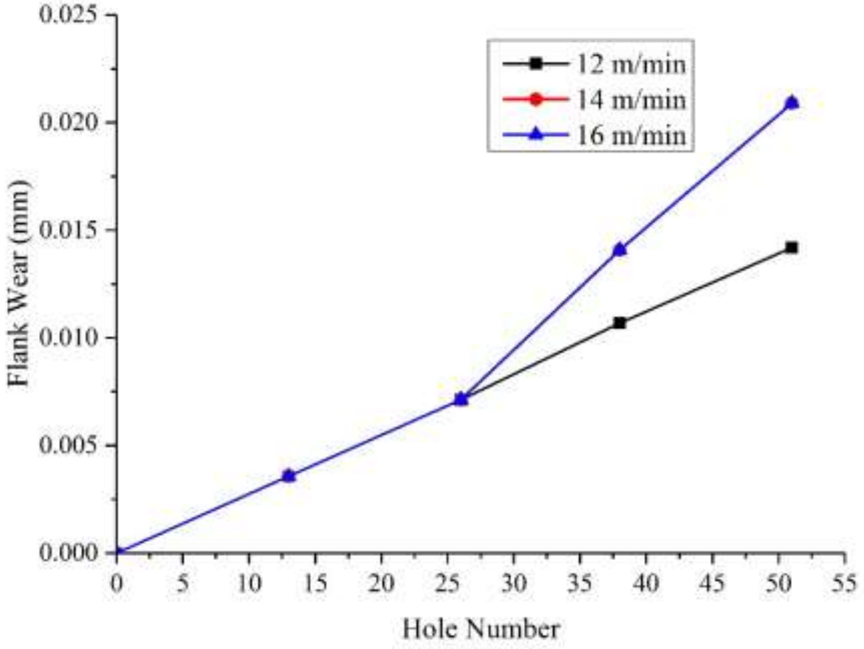


Figure 18. Flank wear after machining 13, 26, 38, and 51 holes for 5 weight percentage of SiC at various speeds.

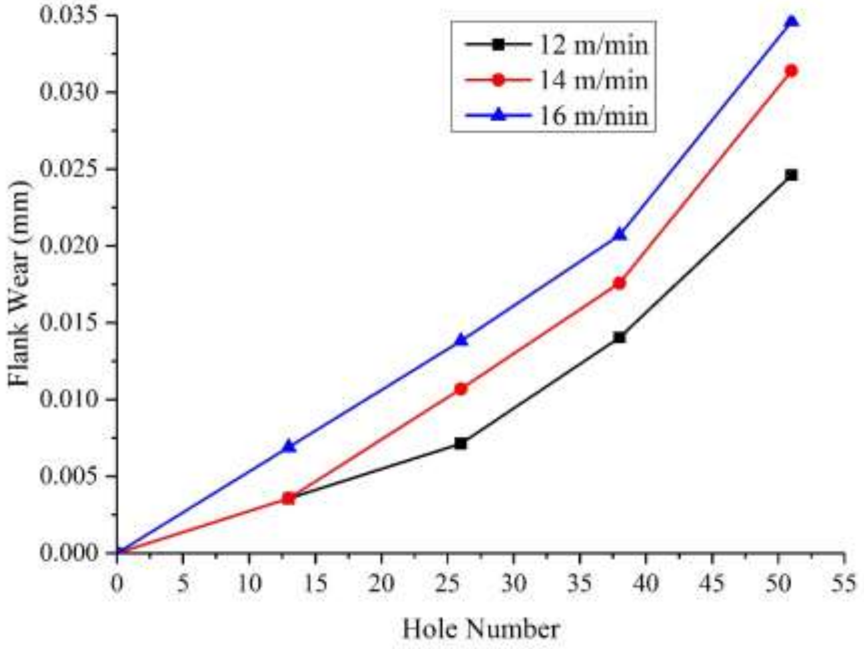


Figure 19. Flank wear after machining 13, 26, 38, and 51 holes for 7.5 weight percentage of SiC at various speeds.

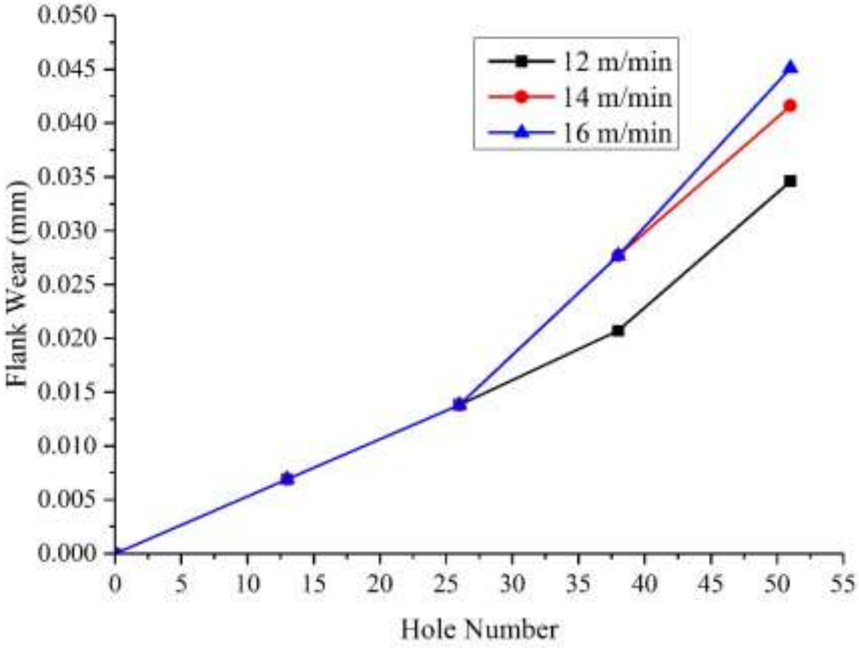


Figure 20. Flank wear after machining 13, 26, 38, and 51 holes for 10 weight percentage of SiC at various speeds.

It was observed from Figures 15 to 17 that the value of flank wear increased with weight percentage of SiC. Further, for a particular weight percentage of SiC particles, the increase in the cutting speed resulted in the increase of flank wear, as shown in Figures from 18 to 20. This phenomenon matches very well with the pattern of variation of tool wear that is already reported [24]. In general, the flank wear increased with the increase in the number of holes tapped. As the tapping of holes progressed, the sharpness of cutting edges is lost and the tool becomes dull. It results in the increased requirement of torque for threading. This is confirmed by the pattern of variation of torque as shown in Figures from 10 to 12.

From the Figures 19 and 20, a significant tool wear was observed at the speed of 16 m/min for 7.5 and 10 weight percentage of SiC composite. The maximum progressive flank wear (0.0451mm) was found on the tapping tool for 10 weight percentage of SiC at the speed of 16m/min after tapping 51 holes. The magnitude of flank wear in the tapping tool for 5 (0.0209 mm) and 7.5 weight percentage of SiC (0.0346 mm) at the speed of 16 m/min is less than 10 weight percentage of SiC at the same speed.

It is evident from the graphs that the rate of flank wear is higher for the tapping speed of 16m/min for all the weight percentages of SiC when compared to the same for 12 m/min and 14 m/min. In view of all these, it may be inferred that the cutting speed is more satisfactory in the range of 12 to 14 m/min with the Al6061 composite with 5 to 10 weight percentages of SiC.

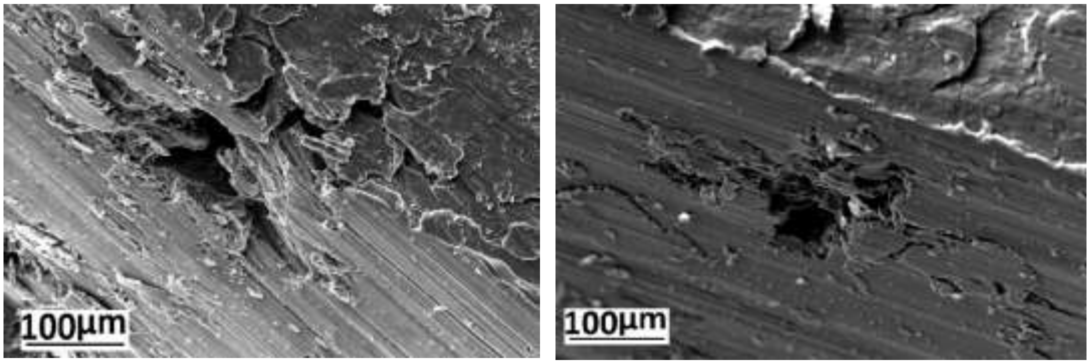
Quality of threads

The quality of threads was investigated by studying the surface morphology of threads and the qualitative assessment of thread profile.

Surface morphology of threads

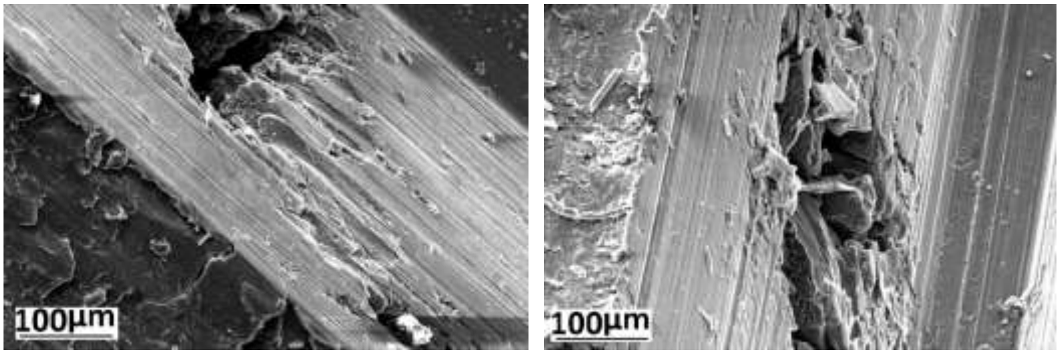
The surface morphology images of the thread surface were captured using EVO MA18 Scanning Electron Microscope (SEM) (Zeiss make). The study of the surface morphology was undertaken to investigate the possible mode of failure of work material causing the formation of chips, during the tapping. It is evident from the SEM images, shown in Figure 21,that the mode of failure of work material is due to ductile fracture of matrix material causing shearing of chips. It also reveals the possible debonding or dislodging of SiC particles, during the process.

The common defects in the machining of metal matrix composites are work hardening of the soft matrix and cracking or debonding of the particles. When compared to other defects of cast components such as gas porosity, such machining induced defects are minor and can be ignored [25]. From SEM images, shown in Figures 21 and 23, it is evident that the increase in weight percentage of SiC particles from 5 to 10 has given rise to increased tendency of dislodging of SiC particles. Further, from Figures 22(b) and 23(b), it is evident that the tendency for dislodging of SiC particles from the thread surface increases with the increase in the cutting speed. With the increase in the number of holes tapped, the flank of the cutting edge of the tap may be worn out due to the dislodged SiC particles from the root of the threads, as shown in Figures 22(b) and 24(b). The debonded SiC particles are shown in Figure 23(a). Such debonded particles entrapped between the flank of cutting edge of tool and root of thread surface during the tapping act as abrasives and cause damage to the root of threads. The dislodged and debonded SiC particles may also affect the surface finish of threads.



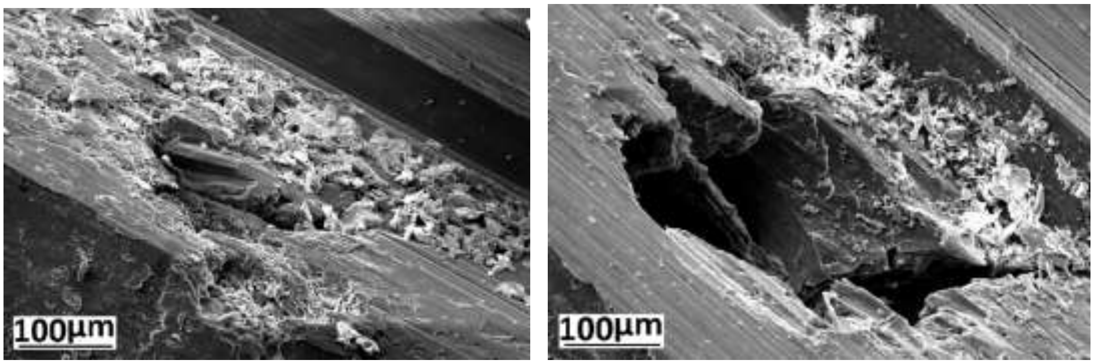
(a) (b)

Figure 21. SEM images (500X) of the tapped surface of Al6061 composite with 5 weight percentage of SiC (51 holes) MMC at a tapping speed of (a) 12 m/min (b) 16 m/min



(a) (b)

Figure 22. SEM images (500X) of the tapped surface of Al6061 composite with 7.5 weight percentage of SiC (51 holes) MMC at a tapping speed of (a) 12 m/min (b) 16 m/min.



(a) (b)

Figure 23. SEM images (500X) of the tapped surface of Al6061 composite with 10 weight percentage of SiC (51 holes) MMC at a tapping speed of (a) 12 m/min (b) 16 m/min.

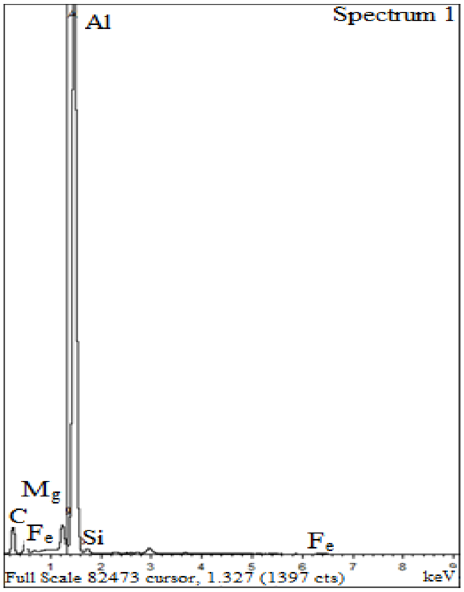


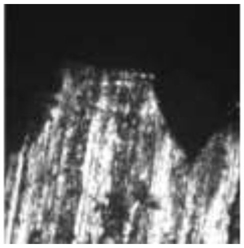
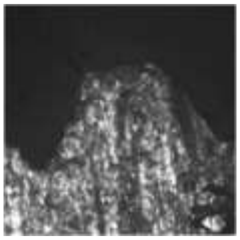
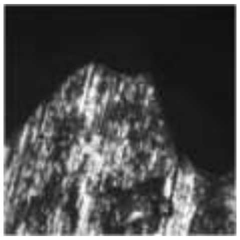
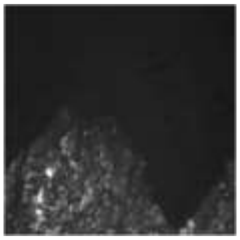
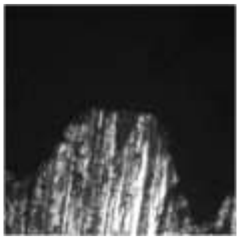
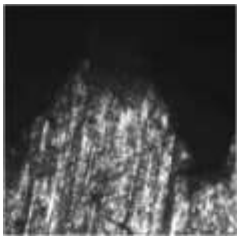
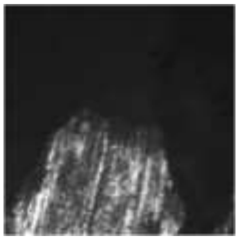
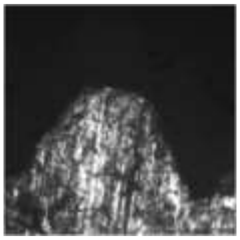
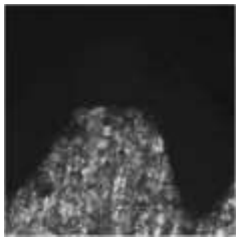
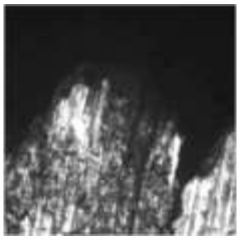
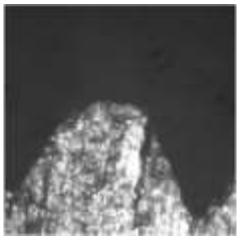
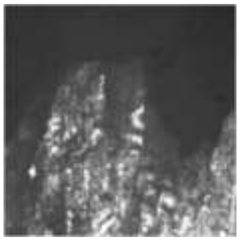
Figure 24. EDAX of thread surface (after 51 holes) of the Al6061composite with 10 weight percentage of SiC, at 16 m/min.

The Energy Dispersive X-ray Spectroscopy (EDAX) analysis conducted for the thread surface of the composite with 10 weight percentage of SiC at 16m/min cutting speed (after 51 holes) is shown in Figure 24. It did not reveal the presence of the elements such as tungsten, chromium, nickel, molybdenum of the tool material on the thread surface. These elements are the main constituents of the HSS taps. From this, it could be concluded that no diffusion of elements of the tool material has taken place to the work material. Therefore, the wear of the tap is due to the adhesion and the abrasion mechanisms and not due to the diffusion.

Quality of profile of the thread

The qualitative assessment of profile of the thread was undertaken by observing the profiles of the sectioned thread samples under Trinocular Inverted metallurgical microscope. The images of profile of the thread for different combinations of weight percentage of SiC, cutting speed, and number of holes are shown in Figure 25.

It is observed in Figures from 25(a) to (f) that the profile of the threads deteriorated with the increase in cutting speed and weight percentage of SiC in the composite. The increase in the percentage of SiC particles increases the number of particles present on profile of the thread, giving rise to a higher probability of dislodging or debonding of particles at the surface of the thread. It is also observed that the increase in speed increases the torque and hence the power required for tapping. In the region of tapping, the increased consumption of power increases the temperature, which may cause thermal softening of the matrix material of Al/SiC MMC. This may increase the intensity of plastic deformation of the matrix material resulting in the deterioration of flank of machined thread. The effect of number of holes tapped on the quality of thread surface is visible while tapping the specimens with all weight percentages of SiC. This phenomenon may be due to the flank surface of the thread being damaged progressively by the dislodged or debonded SiC particles from the matrix material.

Hole number and weight percentage of SiC and in the sample	Cutting Speed		
	12 m/min	14 m/min	16 m/min
(a) Hole number 1, 5 weight percentage SiC (100X)			
(b) Hole number 51, 5 weight percentage SiC (100X)			
(c) Hole number 1, 7.5 weight percentage SiC (100X)			
(d) Hole number 51, 7.5 weight percentage SiC (100X)			
(e) Hole number 1, 10 weight percentage SiC (100X)			

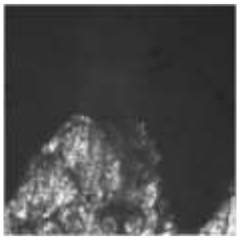
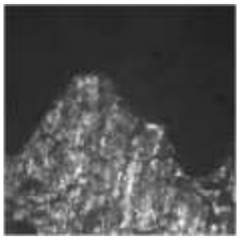
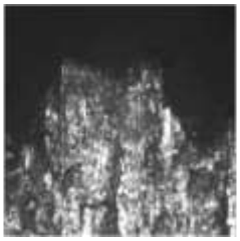
(f) Hole number 51, 10 weight percentage SiC (100X)			

Figure 25. A profile of the thread for different combinations of weight percentage of SiC, cutting speed and number of holes.

CONCLUSIONS

In this experimental investigation, the performance of uncoated HSS machine taps was evaluated in terms of tapping torque, progressive flank wear and surface characteristics of the thread surfaces. The conclusions derived from the outcome of this study are as following:

- The flank wear of uncoated HSS machine taps increases with the increase in weight percentage of SiC in Al/SiC composite for a given cutting speed.
- When the matrix materials are reinforced by the same weight percentage of SiC particles, the flank wear of the tool increases with the cutting speed.
- The maximum progressive flank wear (0.0451mm) was found on tapping tool for 10 weight percentage SiC at a speed of 16m/min after tapping 51 holes. Therefore, the cutting speed in the range of 12 to 14 m/min could be more appropriate for the Al6061/SiC composite with 5 to 10 weight percentages SiC.
- As the weight percentage of the SiC and the cutting speed increase, there would be qualitative deterioration of profile of the thread in the work material.
- During the tapping operation, no diffusion of elements of tool material has taken place to the work material and hence the wear of the tap could be due to the adhesion and the abrasion mechanisms. This needs to be confirmed through further study.

REFERENCES

[1] Santos MC, Machado AR, Sales WF, Barrozo MAS, Ezugwu EO. Machining of aluminum alloys: a review. International Journal of Advanced Manufacturing Technology 2016;86:3067-3080.

[2] Surappa MK, Aluminium matrix composites: Challenges and opportunities. Sadhana Academy Proceedings in Engineering and Sciences 2003; 28:319-334.

[3] Surappa MK. Microstructure evolution during solidification of DRMMCs (Discontinuously reinforced metal matrix composites): State of art. Journal of Material Processing Technology 1997;63:325-333.

[4] Sozhamannan GG, Balasivanandha Prabu S, Venkatagalapathy VSK. Effect of Processing Paramters on Metal Matrix Composites: Stir Casting Process. Journal of Surface Engineered Materials and Advanced Technology 2012;2:11-15.

[5] Skibo DM, Schuster DM, Jolla L. US patents No.4. 1988;786467.

[6] Davim, Paulo J. Machining of Metal Matrix Composites. UK: Sringer Verlag London Limited; 2008.

[7] Ibrahim C, Mehmet T, Seker U. CBN cutting tool wear during machining of particulate reinforced MMCs. Wear 2004;257:1041-1046.

[8] Kilickap E, Cakir O, Aksoy M, Inan A. Study of tool wear and surface roughness in machining of homogenised SiC-p reinforced aluminium metal matrix composite. Journal of Materials Processing Technology 2005;164-165:862-867.

[9] Dabade UA, Jadhav MR. Experimental study of surface integrity of Al/SiC particulate metal–matrix composites in hot machining. Procedia CIRP 2016;41:914-919.

[10] Beristaina J, Gonzaloa O, Sanda A. Machinability of Al-SiC metal matrix composites using WC, PCD and MCD inserts. Revista De Metalurgia 2014; 50: 1-6.

[11] Yanming Q, Zehua Z. Tool wear and its mechanism for cutting SiC particle-reinforced aluminium matrix composites. Journal of Materials Processing Technology 2000;100:194-199.

[12] Gil-Del-Val A, Diéguez PM, Arizmendi M, Estrems M. Experimental study of tapping wear mechanisms on nodular cast iron. Proceedia Engineering 2015; 132: 190-196.

[13] Saito Y, Takiguchi S, Yamaguchi T, Shibata K, Kubo T, Watanabe W, Oyama S, Hokkirigawa K. Effect of friction at chip–tool interface on chip geometry and chip snarling in tapping process. International Journal of Machine Tools & Manufacture 2016; 107:60–65.

[14] Uzun G, Korkut I. The effects of cutting conditions on the cutting torque and tool life in the tapping process for AISI 304 stainless steel. Materials and technology 2016; 50:275–280.

[15] Bratan S, Novikov P, Roshchupkin S. Application of Combined Taps for Increasing the Shaping Accuracy of the Internal Threads in Aluminium Alloys. Procedia Engineering 2016;150:802 – 808.

[16] Bhowmick S, Lukitsch MJ, Alpas AT. Tapping of Al–Si alloys with diamond-like carbon coated tools and minimum quantity lubrication. Journal of Materials Processing Technology 2010; 210:2142-2153.

[17] Filho SLMR, Vieira JT, Oliveira JA, Arruda EM, Brandao LC. Comparison among different vegetable fluids used in minimum quantity lubrication systems in the tapping process of cast aluminum alloy. Journal of Cleaner Production 2017;140:1255-1262.
[18] Steininger A, Siller A, Bleicher F. Investigations Regarding Process Stability Aspects in Thread Tapping Al-Si Alloys. Procedia Engineering 2015;100:1124 – 1132.
[19] Song WQ, Krauklis P, Mouritz AP, Bandopadhyay S. The effect of thermal ageing on the abrasive wear behaviour of age hardening 2014 Al/SiC and Al/SiC composites. Wear 1995;185:125-130.
[20] Hashim J, Looney L, Hashmi MS. The enhancement of wettability of SiC particles in cast aluminium matrix composites. Journal of Materials Processing Technology 2001;119: 329-335.
[21] CMTI. Machine Tool Design Hand Book. 2nd ed. New Delhi: Tata McGraw Hill, 2004.
[22] Armarego EJA, Chen MNP. Predictive Cutting Models for the Forces and Torque in Machine Tapping with Straight Flute Taps. Annals of the CIRP 2002; 51:75-78.
[23] Kannan S, Kishawy HA. Tribological aspects of machining aluminium metal matrix composites, Journal of Materials Processing Technology 2008;198: 399–406.
[24] Albertelli P, Mussib V, Ravasio C, Monno M. An Experimental Investigation of the Effects of Spindle Speed Variation on Tool Wear in Turning. Procedia CIRP 2012;4:29 – 34.
[25] Piska M, Sliwkova P. Surface Parameters, Tribological Tests and Cutting Performance of Coated HSS Taps. Proceedia Engineering 2015;100:125-134.